



UNIVERSITI PUTRA MALAYSIA

**UTILIZATION OF SOLAR HEAT FOR THE CONTROL OF COWPEA
SEED BEETLE, CALLOSOBRUCHUS MACILATUS (FABRICIUS)
(COLEOPTERA : BRUCHIDAE)**

MEKASHA CHICHAYBELU WESSENE.

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**UTILIZATION OF SOLAR HEAT FOR THE CONTROL OF COWPEA SEED
BEETLE, *Callosobruchus maculatus* (Fabricius)
(COLEOPTERA: BRUCHIDAE)**

By

MEKASHA CHICHAYBELU WESSENE

**Thesis Submitted to the School of Graduate Studies, Universiti Putra
Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of
Philosophy**

July 2004



Dedicated to
my wife Fasika Hailu and my daughters Tsion Mekasha, Marta W/Senbet and
the late Betselot Mekasha. To my father the late Chichaybelu Wessene, my
mother Alemework Asfaw and my brother Fiseha Chichaybelu.



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in
fulfilment of the requirements for the degree of Doctor of Philosophy

**UTILIZATION OF SOLAR HEAT FOR THE CONTROL OF COWPEA SEED
BEETLE, *Callosobruchus maculatus* (Fabricius)
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MEKASHA CHICHAYBELU WESSENE

July 2004

Chairman: Professor Dzolkhifli Omar, Ph.D.

Faculty: Agriculture

A survey, consisting of two hundred sample farmers, was conducted in major cool-season food legume growing regions of Ethiopia. Assessment of grain legume seeds collected from sample farmers' stores revealed the importance of adzuki bean beetle, *C. chinensis* (L.). Storage pests were more serious in mid altitude than highland areas. Farmers realized the negative effect of storage insect pests on marketability, consumption quality and viability of legume seeds. Hence, development of economically feasible and environmentally friendly control options is needed.

Biology of *C. maculatus* was studied on adzuki bean seeds in Malaysia at UPM. Mated female bruchid laid 61.8 eggs on average in its life with reproductive

effort of 11.6. Eggs had average incubation period of 4.6 days and mean hatchability rate of 77.9%. Four larval instar stages were recognized. The insect had mean developmental period of 27.8 days with adult emergence rate of 62.0%. Number of eggs had strong negative relation to age of female bruchid while developmental period had positive relation.

Obtuse-base-angle box heaters glued from inside with aluminum foil had better ability in trapping solar energy where 118° base-angle box had significantly high performance. Square box heaters painted black from inside trapped higher solar energy with better performance of boxes of 10 cm height, though not as capable as the obtuse-base-angle box heaters. The different glazing thicknesses and glazing layers did not show significant effect on the extent of trapped energy. Box heater of 118° base angle, glued from inside with aluminum foil was, therefore, promoted for further evaluation of the effect of heating on *C. maculatus*, due to its better performance in trapping solar energy.

Effect of heat treatment on *C. maculatus* and adzuki bean seed moisture content and germination was evaluated. Exposure of the various developmental stages of *C. maculatus* to heat for up to 45 minutes raised the temperature between and within the seeds well in excess of the lethal level and resulted in complete control. Treatment of adzuki bean seeds with heat for up to one hour did not significantly affect seed viability. Though there was no significant difference, about 18.6% and 27% loss in seed viability resulted from seeds treated for 30 and 60 minutes, respectively, should not be undermined. Hence,

adzuki bean seeds meant for planting should not be heat treated to control storage insect pests. However, heat treatment had no much effect on seed moisture content.

Assessment on the effect of seed layer thickness on the efficacy of heat treatment against *C. maculatus* revealed that up to 3 cm thickness of adzuki bean seed can be treated at a time, as neither adult bruchids survived heat treatment nor emerged later. Therefore, solar heating of infested adzuki bean seeds using the aforementioned box heater around noon for an hour can give effective control of *C. maculatus*.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PENGUNAAN HABA DARIPADA TENAGA SURIA UNTUK MENGAWAL
KUMBANG BIJIRIN KACANG DUDUK, *Callusobruchus maculatus*
(Fabricius)
(COLEOPTERA: BRUCHIDAE)**

Oleh

MEKASHA CHICHAYBELU WESSENE

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Satu bancian yang terdiri seramai 200 petani telah dijalankan di kawasan utama penanaman kekacang musim sejuk di Ethiopia. Penilaian terhadap bijirin kekacang simpanan yang di perolehi daripada sampel petani yang di banci menunjukkan pentingnya kumbang kacang merah, *C. chinensis* (L.). Perosak simpanan adalah lebih teruk di altitud pertengahan di bandingkan dengan kawasan tanah tinggi. Petani sedar kesan buruk akibat serangan perosak simpanan terhadap pemasaran, kualiti remekanan dan kebolehidip biji kacang. Oleh yang demikian pembentukan suatu kaedah pengawalan yang murah dan mesra alam adalah diperlukan.

Biologi *C. maculatus* telah dikaji dengan menggunakan biji kacang merah. Dalam jangkahayat kumbang betina bruchid yang sudah mengawan purata 61.8 biji telur di hasilkan dengan keupayaan membiak 11.6. Purata jangkamasa pengeraman telur ialah 4.6 hari dan purata peratus penetasan ialah 77.9. Terdapat 4 instar larva. Purata jangkamasa tumbesaran adalah 27.8 hari manakala kadar kemunculan dewasa ialah 62%. Bilangan telur mempunyai korelasi negatif dengan umur kumbang betina manakala korelasi dengan jangkamasa tumbesaran adalah positif.

Alat pemanas berbentuk sudut dasar cukah yang dilapik dengan kepingan aluminium mempunyai keupayaan yang baik didalam memerangkap tenaga suria di mana kotak bersudut 118° memberi prestasi yang signifikan. Kotak pemanas berbentuk 4 segi empat sama yang dicat hitam di bahagian dalam memerangkap tenaga suria yang tinggi dengan prestasi yang baik di tunjukkan oleh kotak yang tingginya 10 cm, walaupun tidak sebaik alat manas sudut dasar cukah.

Bahan pengupaman yang berbeza ketebalan dan lapisan tidak menunjukkan kasan yang nyata didalam memerangkap tenaga suria. Kotak pemanas bersudut 118° yang gam dengan kepingan aluminium telah dipilih untuk kajian seterusnya bag menentukan keberkesanannya untak mengawal *C. maculatus*. Ini disebabkan alat ini telah didapati mempunyai keupayaan yang tinggi memerangkap tenaga suria.

Kesan rawatan haba terhadap *C. maculatus* dan kandungan air dan kesuburan kacang merah telah dikaji. Pendedahan haba terhadap berbagai peringkat hidup *C. maculatus* selama 45 minit telah meningkatkan suhu di antara dan di dalam biji tanpa melebihi tahap maut bijirin dan seterusnya mengakibatkan kawalan serangga yang sepenuhnya. Rawatan haba terhadap kacang merah selama 1 jam tidak mempengaruhi secara nyata, kebolehd hidup biji. Walaupun tidak tendapat perbezaan bererti, kebolehd hidup biji yang menurun 18.6% dan 27% masing-masing setelah dirawat selama 30 dan 60 minit tidak seharusnya di ketepikan. Oleh yang demikian biji kacang merah yang hendak dijadikan benih tidak seharusnya diberi rawatan haba. Walau bagaimanapun, rawatan haba tidak memberi kesan terhadap kandungan air biji.

Penilaian ke atas kesan ketebalan lapisan biji kacang merah terhadap efikasi rawatan haba bagi mengawal *C. maculatus* menunjukkan lapisan kacang merah setebal 3 cm boleh dirawat pada satu masa, di mana dewasa bruchid tidak mandir dan tidak menjelma. Oleh itu rawatan haba suria terhadap kacang merah dengan menggunakan alat pemanas sudut dasar cukah pada waktu tengah hari selama 1 jam boleh mengawal *C. maculatus*.

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I certify that an Examination Committee met on 22nd July 2004 to conduct the final examination of Mekasha Chichaybelu Wessene on his Doctor of Philosophy thesis entitled "Utilization of Solar Heat for the Control of Cowpea Seed Beetle, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae)" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for the quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted to any other degree at UPM or other institution.



MEKASHA CHICHAYBELU WESSENE

Date: *11 August 2008*

TABLE OF CONTENTS

	Page
DEDICATION	II
ABSTRACT	III
ABSTRAK	VI
ACKNOWLEDGMENTS	IX
APPROVAL	X
DECLARATION	XII
LIST OF TABLES	XVI
LIST OF FIGURES	XVIII
LIST OF PLATES	XXI
CHAPTER	
1. INTRODUCTION	1
2 LITERATURE REVIEW	5
2.1 Legumes (Pulses) and their Major Post-Harvest Insect Pests	5
2.2 Importance of Bruchids	10
2.3 Description and Biology of Major <i>Callosobruchus</i> spp.	15
2.4 Development in Tackling Storage Pest Problems	21
2.5 Mechanisms of Action of Extreme Temperatures in Affecting Insects	25
2.6 Solar Energy: Its Collection and Utilization in Agriculture	26
2.6.1 Solar Energy and Its Collection	26
2.6.2 Utilization of Solar Energy in Agriculture	32
3 IMPORTANCE OF STORAGE PESTS OF COOL-SEASON FOOD LEGUMES IN THE MAJOR GROWING REGIONS OF ETHIOPIA	38
3.1 Introduction	38
3.2 Materials and Methods	39
3.2.1 Location of the Study	39
3.2.2 Assessment of Farmers' Perception on Cool-Season Food Legumes Storage Pest Problems and their Management	40
3.2.3 Determination of Level of Infestation and Extent of Damage Incurred by Post-Harvest Insect Pests of Cool-Season Food Legumes in Major Growing Regions of Ethiopia	40
3.2.4 Data Analysis	41
3.3 Results and Discussion	41
3.3.1 Farmers' Perception on Cool-Season Food Legumes Post-Harvest Pest Problems and their Management	41



3.3.2	Level of Infestation and Extent of Damage Incurred due to Post-Harvest Insect Pests of Cool-Season Food Legumes in Major Growing Regions of Ethiopia	58
4	STUDY ON THE BIOLOGY OF <i>CALLOSOBRUCHUS MACULATUS</i> (FABRICIUS) ON ADZUKI BEAN, <i>VIGNA ANGULARIS</i> (WILLD.) OHWI & OHASHI	64
4.1	Introduction	64
4.2	Materials and Methods	65
4.2.1	Stock Culture Development and Seed Maintenance	65
4.2.2	Oviposition and Egg Hatchability	65
4.2.3	Development of Immature Stages and Adult	66
4.2.4	Data Analysis	67
4.3	Results and Discussion	67
4.3.1	Fecundity and Egg Hatchability	67
4.3.2	Development of Immature Stages and Adult	71
5	DETERMINATION OF SOLAR ENERGY TRAPPING CAPACITY OF SOLAR HEATERS WITH DIFFERENT CONSTRUCTION MATERIALS AND DESIGNS	76
5.1	Introduction	76
5.2	Materials and Methods	77
5.2.1	Equipments	77
5.2.2	Solar Heater Construction	77
5.2.3	Temperature Recording	79
5.2.4	Determination of Solar Energy Trapping Capacity of Obtuse- Base-Angle Box Heaters of Different Base Angle Glued from Inside with Copper Shim or Aluminum Foil	81
5.2.5	Determination of Solar Energy Trapping Capacity of Square Box Heaters of Different Box Height and Black Painting	83
5.2.6	Evaluation of Effect of Thickness of Clear Plastic Sheet Glazing on Solar Energy Trapping Capacity of Obtuse-Base-Angle Box Heaters Glued from Inside with Aluminum Foil	85
5.2.7	Evaluation of Effect of Glazing Layers of Clear Plastic Sheet on Solar Energy Trapping Capacity of Obtuse-Base-Angle Box Heaters Glued from Inside with Aluminum Foil	86
5.2.8	Data Analysis	87
5.3	Results and Discussion	88
5.3.1	Solar Energy Trapping Capacity of Obtuse-Base-Angle Box Heaters of Different Base Angle Glued from Inside with Copper Shim or Aluminum Foil	88
5.3.2	Solar Energy Trapping Capacity of Square Box Haters of Different Height and Black Painting	94

5.3.3	Over all Comparison of the Various Box Heaters	100
5.3.4	Effect of Thickness of Clear Plastic Sheet Glazing on Solar Energy Trapping Capacity of Obtuse-Base-Angle Box Heaters Glued with Aluminum Foil from Inside	101
5.3.5	Effect of Number of Glazing Layers of Clear Plastic Sheet on Solar Energy Trapping Capacity of Obtuse-Base-Angle Box Heaters Glued with Aluminum Foil from Inside	105
6	EVALUATION OF EFFECT OF HEATING ON DEVELOPMENTAL STAGES OF <i>C. MACULATUS</i> AND ADZUKI BEAN, <i>V. ANGULARIS</i> , SEED GERMINATION AND MOISTURE CONTENT	110
6.1	Introduction	110
6.2	Materials and Methods	111
6.2.1	Equipments	111
6.2.2	Solar Simulation and Temperature Recording	111
6.2.3	Stock Culture Development and Seed Maintenance	113
6.2.4	Determination of Effect of Heat Treatment on Oviposition and Adult Mortality	113
6.2.5	Determination of Effect of Heat Treatment on Hatchability of Eggs	114
6.2.6	Determination of Effect of Heat Treatment on Larval Instars and Pupae	115
6.2.7	Determination of Effect of Heat Treatment on Adzuki Bean, <i>V. angularis</i> , Seed Germination and Moisture Content	116
6.2.8	Determination of Thickness of Adzuki Bean, <i>V. angularis</i> , Seed Layer (Amount of Seed) to be Treated with Heat at a Time to Control <i>C. maculatus</i>	117
6.2.9	Data Analysis	117
6.3	Results and Discussion	118
6.3.1	Effect of Heat Treatment on Adult Mortality and Oviposition	118
6.3.2	Effect of Heat Treatment on Egg Hatchability	120
6.3.3	Effect of Heat Treatment on Larval Instars and Pupae	122
6.3.4	Effect of Heat Treatment on Adzuki Bean, <i>V. angularis</i> , Seed Germination and Moisture Content	126
6.3.5	Thickness of Adzuki Bean, <i>V. angularis</i> , Seed Layer (Amount of Seed) to be Treated with Heat to Control <i>C. maculatus</i>	129
7	CONCLUSIONS	132
	REFERENCES	136
	APPENDICES	148
	BIODATA OF THE AUTHOR	167



LIST OF TABLES

Table	Page
1 The response of stored product insects to temperature	25
2 Merits of cool-season food legume production as indicated by farmers	43
3 Major field and storage pests of cool-season food legumes as perceived by the farmers	44
4 Storage structures and their relative utilization by farmers	46
5 Farmer's perception on severity of storage insect pest attack in different storage structures	47
6 Relative implementation of control methods against storage insect pests of cool-season food legumes by farmers	48
7 Proportion (%) of farmers using insecticides against storage insect pests of cool-season food legumes by location	52
8 Proportion (%) of farmers using different botanical insecticides against storage insect pests of cool-season food legumes	54
9 Utilization of cool-season food legumes damaged by storage pests as perceived by farmers	55
10 Average level of infestation and extent of damage caused by storage insect pests on chickpea and grass pea sample seeds taken from farmers' stores	59
11 Average level of infestation and extent of damage caused by storage insect pests on field pea and faba bean sample seeds taken from farmers' stores	60
12 Paired comparison (t-value) for the number of eggs laid at various age of female <i>C. maculatus</i>	68
13 Paired comparison (t-value) for incubation period of eggs laid at various age of female <i>C. maculatus</i>	71
14 Paired comparison (t-value) for percent hatchability of eggs laid at various age of female <i>C. maculatus</i>	71
15 Paired comparison (t-value) for emergence rate of adults developed from eggs laid at various age of female <i>C. maculatus</i>	73



16	Paired comparison (t-value) for developmental period of <i>C. maculatus</i> developed from eggs laid at various age of females	75
17	Summary of <i>C. maculatus</i> biology on adzuki bean	75
18	Between-seed temperature at 30 minutes interval of solar exposure in obtuse-base-angle box heaters glued from inside with either copper shim or aluminum foil	92
19	Within-seed temperature at 30 minutes interval of solar exposure in obtuse-base-angle box heaters glued from inside with either copper shim or aluminum foil	92
20	Between-seed temperature at 30 minutes interval of solar exposure in square box heaters painted black from either inside or outside	98
21	Within-seed temperature at 30 minutes interval of solar exposure in square box heaters painted black from either inside or outside	99
22	Between-seed temperature as affected by glazing thickness of clear plastic sheet in obtuse-base-angle box heater glued with aluminum foil from inside as a result of exposure to solar light	104
23	Within-seed temperature as affected by glazing thickness of clear plastic sheet in obtuse-base-angle box heater glued with aluminum foil from inside as a result of exposure to solar light	104
24	Between-seed temperature as affected by glazing layers of clear plastic sheet in obtuse-base-angle box heaters glued with aluminum foil from inside as a result of exposure to solar light	108
25	Within-seed temperature as affected by glazing layers of clear plastic sheet in obtuse-base-angle box heaters glued with aluminum foil from inside as a result of exposure to solar light	108



LIST OF FIGURES

Figure	Page
1 Relationship between major bruchid genera and legume genera	8
2 Farmers' allocation of farmland for cool-season food legumes production as related to the total farmland	42
3 Farmers' estimate on market price of cool-season food legume seeds attacked by bruchids compared to not attacked seeds	56
4 Germination rate of bruchid attacked legume seeds relative to not attacked seeds as perceived by sample farmers	57
5 Effect of bruchid attack on consumption quality of cool-season food legumes as perceived by sample farmers	57
6 Relation between level of infestation of legume seeds expressed by proportion of seeds with bruchid eggs (%) and altitude	62
7 Relation between extent of damage of cool-season food legumes expressed by proportion of seeds with bruchid adult emergence hole (%) and altitude	62
8 Average number of eggs laid per female per day as related to age of egg laying <i>C. maculatus</i> female	68
9 Incubation period and hatchability rate (\pm standard error) of <i>C. maculatus</i> eggs	70
10 Larval instars of <i>C. maculatus</i> as indicated by head capsule width	72
11 Rate of adult emergence and mean developmental period in days (\pm standard error) of <i>C. maculatus</i>	73
12 Trend in between-seed temperature increment in obtuse-base-angle box heaters glued from inside with copper shim or aluminum foil due to exposure to sun light	89
13 Trend in within-seed temperature increment in obtuse-base-angle box heaters glued from inside with copper shim or aluminum foil due to exposure to sun light	90
14 Trend in between-seed temperature increment in square box heaters of different box height painted black from inside or from outside due to exposure to sun light	96



15	Trend in within-seed temperature increment in square box heaters of different box height painted black from inside or from outside due to exposure to sun light	97
16	Between-seed temperature in obtuse-base-angle box heaters glued with aluminum foil from inside as affected by thickness of clear plastic sheet glazing under exposure to sun light	102
17	Within-seed temperature in obtuse-base-angle box heaters glued with aluminum foil from inside as affected by thickness of clear plastic sheet glazing under exposure to sun light	103
18	Between-seed temperature in obtuse-base-angle box heaters glued with aluminum foil from inside as affected by different glazing layers of clear plastic sheet under exposure to sun light	106
19	Within-seed temperature in obtuse-base-angle box heaters glued with aluminum foil from inside as affected by different glazing layers of clear plastic sheet under exposure to sun light	107
20	Mortality of adult <i>C. maculatus</i> (\pm standard error) as affected by heat treatment for different durations	119
21	Number of eggs laid per heat treated female <i>C. maculatus</i> during the first three days (\pm standard error) after emergence	119
22	Hatchability (\pm standard error) <i>C. maculatus</i> eggs as affected by heat treatment for different durations	121
23	Hatchability of <i>C. maculatus</i> eggs (\pm standard error) laid by adults treated with heat for different durations	122
24	Number of <i>C. maculatus</i> adults emerged (\pm standard error) from first instar larvae treated with heat for different durations	123
25	Number of <i>C. maculatus</i> adults emerged (\pm standard error) from second instar larvae treated with heat for different durations	124
26	Number of <i>C. maculatus</i> adults emerged (\pm standard error) from third instar larvae treated with heat for different durations	124
27	Number of <i>C. maculatus</i> adults emerged (\pm standard error) from fourth instar larvae treated with heat for different durations	125
28	Number of <i>C. maculatus</i> adults emerged (\pm standard error) from pupae treated with heat for different durations	126



29	Germination of adzuki bean, <i>V. angularis</i> , seeds (\pm standard error) as affected by heat treatment of different durations	127
30	Loss in Adzuki bean, <i>V. angularis</i> , seed moisture content (\pm standard error) due to heat treatment for different durations	129
31	Effect of adzuki bean, <i>V. angularis</i> , seed layer thickness on the control of <i>C. maculatus</i> by heat treatment (\pm standard error)	130



LIST OF PLATES

Plate	Page
1 Traditional storage structures used by farmers in Ethiopia: Upper - Goteru; Lower - Gota (Dibignit)	45
2 Adzuki bean, <i>Vigna angularis</i> , seed (left) and adult <i>Callosobruchus maculatus</i> (right)	64
3 Obtuse-base-angle box heater glued from inside with:- upper: copper shim; lower: aluminum foil	78
4 Square box heater: - upper: painted black from inside; lower: painted black from outside	80
5 Intech Micro 2100-A16 data logger showing thermocouple connection for temperature recording	81
6 Square frame of angled-iron used to fix glazing plastic to box heaters	82
7 Partial view of obtuse-base-angle box heater experiment	84
8 Square metal frame placed between glazing plastic sheet for double and triple glazing	87
9 Heat treatment with solar simulator	112



CHAPTER 1

INTRODUCTION

The importance of pulses (legumes) lies in their food value as major source of protein, energy, minerals, vitamins and roughage in addition to their miscellaneous uses in animal feed, soil fertility maintenance and industry. In many tropical developing countries of the world, pulses supply a high proportion of the plant proteins which are not only the main, but also the cheapest source of protein in areas where animal protein are scarce and too expensive for a large proportion of the population (Okigdo, 1978). In addition to the above-mentioned uses Telaye *et al.* (1994) reported that stalks of pulses are used as a source of fuel for cooking purposes.

Preserving the harvested crop without loss or damage is a problem of every nation. In tropical climate, deterioration of stored material, aided by insect damage and moulds, can be rapid (Hill, 1997). The wide variety of materials that humans accumulate and store in containers ranging from large bins to small boxes present conducive environmental conditions for certain insects thrive, essentially free of any natural enemies (Romoser and Stoffolano, 1998). In developing countries much produce is kept in on-farm stores in small quantities under quite primitive conditions that are liable for insect pest infestation. Hence destruction of food by stored grain insect pests is one of the

major factors responsible for the low levels of subsistence in many tropical countries.

Most representatives of stored-product insect pests can reproduce and infest all round the year (Zakladni and Ratanova, 1987). Moreover, most of this group of pests have short developmental periods and thus have several generations a year. On the other hand, fluctuations in temperature and moisture content in the store are low and hence stored grain pests suffer less from extreme conditions. Therefore, the high fecundity and quick development of these pests can, under optimal conditions, result in a catastrophically fast increase in their population.

Hence, the direct feeding of insect pest on stored grains results in weight losses that can end up in the commercial loss of the whole grain. These pests also cause loss in quality of stored grains. Loss of seed viability, among other factors, may be caused by insect infestation where insects that selectively attack the germ will cause greater loss than others. Infestation generally results in dissatisfied customers and related marketing problems that develop from a poor reputation in marketing channels. Most unfortunate consequence of not managing grain properly is the loss of money, time and effort to produce grain.

Bruchids (Coleoptera: Bruchidae) are among the important constraints in grain legume production. They cause considerable quantitative and qualitative losses to stored legumes. Due to this, farmers are often reluctant to grow legumes, as they have to dispose of their produce immediately after harvest, even though the market price may not be remunerative at that time (Chauhan and Ghaffar, 2002).

Synthetic pesticides are currently the method of choice to protect stored grain from insect damage. However, their widespread use has led to the development of pest strains resistant to insecticides and pest resurgence (Subramanyam and Hagstrum, 1995; Pedigo, 1999). Moreover, they are hazardous to other species than those they are intended to control and unsafe to the environment (Kitch *et al.*, 1992; Shaaya *et al.*, 1997). On the other hand, the utilization of such products is less feasible for low resource farmers. These factors call for a demand for safer and cheaper alternatives to be integrated in the management of the pests.

One technique that has been used successfully for many years against stored product pests is the use of extreme temperature. The potential of using solar energy in controlling storage insect pests through heating of grains in various types of solar heaters has been reported earlier (Nakayama *et al.*, 1983; Murdock and Shade, 1991; Kitch *et al.*, 1992; Mohammed *et al.*, 2001;